LLNL Environmental Restoration Division Standard Operating Procedure	TITLE: Well Development
APPROVAL Date ____________________ ________ Livermore Site Deputy Program Leader	PREPARERS: J. Gardner*, S. Gregory, J. Hoffman*, and S. Nelson* REVIEWERS: R. Bainer, L. Berg*, T. Carlsen, R. Devany*, V. Dibley, and M. Dresen*
APPROVAL Date ____________________ ________ Division Leader CONCURRENCE Date ____________________ ________ QA Implementation Coordinator	PROCEDURE NUMBER: ERD SOP-1.5 REVISION: 2 EFFECTIVE DATE: December 1, 1995 Page 1 of 13

***Weiss Associates**

1.0 PURPOSE

To enhance well efficiency and subsequent water sample quality by removing materials introduced into the ground water, water-bearing formation, sand pack, and well screen during drilling and well installation.

2.0 APPLICABILITY

This procedure is applicable for all personnel performing well development operations, and should be fully reviewed prior to conducting these activities.

3.0 REFERENCES

3.1 Barcelona, M. J., J. P. Gibb, J. A. Helfrich, and E. E. Garske (1985), *Practical Guide to Ground Water Sampling*, U.S. Government Printing Office, EPA 600/2-85/104.

3.2 Driscoll, F. G. (1986), *Groundwater and Wells*, Johnson Division, St. Paul, Minnesota.

4.0 DEFINITIONS

4.1 Air Lifting Pumping

The process by which well water is hydraulically forced to the surface by lowering its specific gravity by pumping compressed air through an air line into a submerged eductor pipe (Driscoll, 1986).

4.2 Imhoff Cone

A graduated clear plastic cone used to measure the volume of silt and sand that is present in water.

4.3 Rawhiding

The process of pulsing compressed air into formation ground water in the screened interval of a well to loosen trapped fine sediment in the filter pack. Air pressure is increased for several seconds, then decreased suddenly. This process causes the column of water in the well to rise and fall, breaking fine sediment and drilling mud free from the filter pack.

4.4 Redox Potential (Eh)

The potential for water to either oxidize (loss of electrons) or reduce (gain of electrons) dissolved constituents. Readings are made in millivolts.

4.5 Specific Conductance

A measurement of the electrical conductivity of water. Specific conductance is measured in microhmos per cm and is a function of ion concentration.

4.6 Surge Block

A well development device composed of one or more round rubber seals attached to a rod. The rubber seals are similar to the diameter of the well casing. As the rod is lowered and raised, a suction is created which helps to loosen and pull the silt and clay fines into the well. The fines then can be removed by pumping or bailing.

4.7 Turbidity

A measurement of water clarity.

5.0 RESPONSIBILITIES

Note: The following responsibilities (Sections 5.1–5.5) are listed by the appropriate level of authority to ensure that proper representation for all procedures and regulations related to this SOP are met.

5.1 Division Leader

The Division Leader’s responsibility is to ensure that all activities performed by ERD at the Livermore Site and Site 300 are performed safely and comply with all pertinent regulations and procedures, and provide the necessary equipment and resources to accomplish the tasks described in this procedure.

5.2 Hydrogeologic Group Leader (HGL)

The HGL's responsibility is to ensure that proper procedures are followed for activities (i.e., drilling, borehole logging and sampling, monitor well installations and development) and to oversee the disposal of all investigation derived wastes.

5.3 Drilling Supervisor (DS)

The DS plans and coordinates all drilling related activities, ensures that all drilling related activities are performed safely and efficiently (using the proper procedures), and that the data generated from these activities are valuable and representative of the true geologic or physical conditions within the borehole. Such activities may include operation of logging equipment, soil sampling, well installation, and development. The DS is also responsible for:

5.3.1 Coordination of the drilling contractor schedules and equipment needs:

- Coordinate the schedules of multiple drill rigs with the drilling contractor.
- Provide the Work Plan to the drilling contractor and answer questions.
- Negotiate the arrival/start date and drill type.
- Monitor the progress of the drilling and anticipate changes in equipment needs (e.g., auger rig, air-mist rig, mud-rotary rig).

5.4 Drilling Coordinator (DC)

5.4.1 The DC provides the interface between the DS and the field activities including:

- Oversight of the Drilling Geologist (DG) and field activities.
- Coordinate the DG's work load.
- Obtain the necessary equipment, supplies, and release numbers from the Technical Release Representative (TRR) for the drilling contractor.
- Provide guidance and training.
- Inform the DG about procedural changes in areas related to drilling (e.g., changes in sampling requests, cuttings disposal issues, new forms, etc.).
- Provide technical input to the DG and Study Area Leader (SAL)/Facility Task Leader (FTL).
- Review borehole and geophysical logs.
- Monitor drilling progress on a daily basis.
- Interact with the Quality Assurance (QA)/Quality Control (QC) officer on drilling and soil sampling issues.
- Estimate the contaminants likely to be present, and the quantity of drilling spoils that may be generated.

5.4.2 During the startup of a new drilling phase, the DS works with the DC and SAL/FTL to:

- Create and finalize all related drilling documents (i.e., the Work Plan and Sampling Plan).
- Work with the SAL/FTL to establish drilling locations, schedules, and budgets for each well.
- Determine the protective equipment necessary for personnel in the field.
- Make well completion decisions and specify the well construction details from the SAL/FTL and Hydrogeologic Group Leader (HGL) input.
- Act as the liaison between the SAL/FTL and the DG.
- Coordinates all necessary biological/archeological surveys prior to drilling. Results of the surveys should be forwarded to the SAL/FTL and Environmental Chemistry and Biological Group Leader (ECBGL).

5.5 Drilling Geologist (DG)

The DG's responsibility is to ensure that drilling activities are carried out according to the specifications designated in the Work Plan, Sampling Plan, Site Safety Plan (SSP), Operation Safety Procedure (OSP), and Standard Operating Procedure (SOP). Additionally, the DG must oversee and document all aspects of the drilling/field investigation, including lithologic and geophysical data, well completion and development specifications, activities of the drillers, sampling and workspace monitoring details. The DG is also responsible for:

5.5.1 Site Preparation and Supply Ordering. The DG must:

- Review the Work Plan prepared by the SAL/FTL and DC, and discuss any questions.
- Assemble all necessary materials, including personal protective equipment (PPE).
- Supply tracking and ordering requests.
- Confirm that all necessary security arrangements have been made to permit site access (e.g., schedule escorts, notify the building coordinator of planned activities, arrange for opening of locked gates).
- Confirm that utility locator and mud pit excavations (if necessary) have been arranged with the field personnel.
- Discuss LLNL site planning requirements and utility lines with field personnel and drillers before drilling begins.

5.5.2 Site Safety

- Supply the SSP, OSP, and SOPs to all workers who enter the drill site.
- Monitor and record work space conditions with appropriate monitoring equipment (including FID, PID, etc.) during drilling activity.
- Confirm that appropriate fencing, warning signs, barricades, animal exit ramps (for mud pit), borehole cover and protection are in place.

- Discontinue work and contact the DC if chemical or physical hazards are encountered.

5.5.3 Field Activities

- Coordinate schedules/actions with field personnel.
- Research site hydrogeology to estimate key parameters (e.g., sample target zones, hydrostratigraphic unit depths and thicknesses, and types of contaminants).
- Obtain a field logbook from the Data Management Group (DMG).
- Calibrate and record calibration information for all monitoring equipment.
- Confirm all sample naming conventions with DMG.
- Collect and document samples.
- Handle all changes and corrections to chain-of-custody (CoC) forms and/or analytical requests.
- Inform the DC, SAL/FTLs, and DMG of any sampling or sampling documentation irregularities.
- Report any deviations from the SSPs, OSPs, or SOPs to the QA/QC Officer.
- If SOPs are violated, a nonconformance report is to be completed and submitted to the QA/QC officer.
- Report missed turnaround times for analytical sample results to QA/QC Officer.
- Confirm that drilling waste analytical results are consistent with the chosen disposal method.
- Decontaminate all sampling equipment.
- Provide frequent updates and documentation of field activities to the DC, HGL, and SAL/FTL.

5.6 Environmental Chemistry and Biology Group Leader (ECBGL)

The ECBGL's responsibility is to provide biological or chemical information and expertise (i.e., biological surveys, water supplies, chemical field instruments, etc.).

5.7 Field Personnel

The field personnel's responsibilities are to conduct all ERD field work that complies with all established operational and safety procedures, and to inform the HGL when the procedures are inappropriate.

Activities the field personnel are responsible to perform (but are not limited to) are to:

- Collect, store, and ship borehole samples to analytical laboratories.
- Drill, complete wells, log boreholes, and properly develop wells to allow the highest yield and the highest quality samples.

- Communicate the performance of development activities to the HGL and DC to allow for modification of the development methods to improve well yield.

5.8 Site Safety Officer (SSO)

The SSO's responsibility is to ensure the safety of ERD's ongoing operations and facilities and work performed. The SSO's responsibility is to receive the details of potential hazards and procedures for all field activities. The SSO directs this information to the LLNL Hazards Control Department to determine if a new Operational Safety Procedure (OSP) is required, thus assuring that an existing OSP addresses all ES&H issues for each operation.

5.9 Study Area Leaders (SAL)/Facility Task Leader (FTL)

The SAL/FTL are responsible for the overall investigation, planning, assessment, and remediation within a study area.

5.10 Technical Release Representative (TRR)

The TRR is responsible for the acquisition and administration of blanket contract releases for the procurement of goods and services. The TRR has the authority to obligate LLNL for payment of goods and services, delegated by the LLNL Business Manager through the LLNL Procurement Department.

5.11 Treatment Facility Hydrogeologist (TFH)

The TFH is responsible for helping the FTL determine borehole location and target zone for completion.

6.0 PROCEDURE

The primary methods used to develop wells are surge-block/bail and air lift. These techniques are used to increase well production and reduce water turbidity by removing introduced sediments from the formation filter pack and well screen area.

6.1 Office Preparation

6.1.1 The DG should obtain relevant information on each well to be developed (e.g., drilling technique, drilling fluid losses, anticipated aquifer yield, screened interval, anticipated contaminants, etc.).

6.1.2 The DG should obtain materials listed in the Equipment Checklist (Attachment A).

6.1.3 The DG should review associated SOPs and pertinent sections of the SSP.

6.1.4 The DC should coordinate schedules/actions with the DG.

6.2 Field Preparation

6.2.1 Decontaminate all equipment used in well development per SOP 4.5, "Equipment Decontamination."

6.2.2 Obtain sufficient collection containers such as 55 gal drums or portable tankers for temporary storage of well development water according to SOP 4.7, “Treatment and Disposal of Well Development and Well Purge Fluids.” Ensure that:

A. Containers have no leaks.

B. Containers, such as 55 gal drums, are stabilized to prevent spillage.

C. Containers are field manageable. The use of truck- or trailer-mounted tanks may be necessary for particularly large volumes of water.

D. Containers are labeled as non-potable purge water.

6.2.3 Follow the instructions pertaining to conducting field work per SOP 4.1, “General Instructions for Field Personnel.”

6.3 Operation

6.3.1 Well development should be performed as soon as practical after well installation. Development may be performed prior to fully installing the sanitary seal, as determined by the DS or designee. An outside water source should not be used to aid development, except under special conditions as defined below. Any outside source of water should be approved by the ECBGL prior to use.

6.3.2 Measure depth to water according to SOP 3.1, “Water Level Measurement,” and measure the total depth of the well.

6.3.3 Record all information on the Well Development Data form (Attachment B).

6.3.4 Remove any residual drilling mud from the casing by bailing or flushing with potable water through a tremie pipe. Introduce just enough water to remove the drilling mud.

6.3.5 Segregate removed drilling mud from the formation water, if possible. Use drilling contractor’s mud tank to collect unthinned drilling mud and initial muddy formation water.

6.3.6 Begin well development using a surge block/bailer based on the number of well casing volumes. Depending on site specific conditions, follow with additional surge-block/bailing, airlift, or a combination of the two methods, as described below. Continue until the water is nearly sediment-free as described below:

A. Use a surge-block/bailer until the water is clear. If a well cannot produce enough formation water because the aquifer yields insufficient water, small amounts of potable water may be introduced. When most of the sediment is removed, continue development with formation water only, if possible.

B. To prevent forcing a pocket of air into the sand pack and possibly reducing the yield of the well, it is important to use dual tube airlifting. This process involves diverting an air line into an educator pipe in the well to create a vacuum that “lifts” the ground water to the surface. Two-inch PVC as the educator pipe, and 1-in. tremie pipe with a “J” attachment as the air line may be used. In this arrangement, the “J” end extends several inches into the bottom opening of the 2-in. PVC. At the surface, compressed air is fed through the tremie pipe, travels down through the submerged “J” tube, and travels back to the surface through the 2-in. PVC. This process creates a vacuum in the PVC casing that “lifts” the ground water out of the well and allows for easy containment of the purged water. Air lifting should start at the top of the sand pack and move down until the entire sand pack interval is developed.

C. Start dual-tube air lifting about 10 ft above the top of the screen, and use just enough air pressure to develop a flow. Gradually increase air pressure to maximize flow. Make periodic water level measurements to ensure the water level in the well casing does not fall below the top of the screen. Surge air pressure periodically to make the water column "bounce." Move the air line down into the screen as the water clears. Note the time it takes for the water to clear between successive rounds of surging. Effective surging is indicated by decreasing time for water to clear. Ensure that the compressed air is filtered before introduction into the well. All collected purge water should be treated or disposed in accordance with SOP 4.7.

6.3.7 Visually note the initial water color and clarity of the purge water, and record on the Well Development Data form (Attachment B). Determine the pH (using pH paper), and note any odor of the water and record on the Well Development Data form. The pH is checked primarily to ensure there is no grout or cement contamination. The majority of the ground water falls in a pH range of between 7 and 9. If the pH of the development water is above 9.5, the condition of the well should be evaluated for grout invasion. This is especially apparent if the pH is higher at the start of development and slowly declines as more water is removed from the well, but rises to higher levels upon ceasing the purging process. Further air development may need to be performed until a lower pH is obtained.

6.3.8 Periodically record descriptions of development method, flow rate, water clarity, odor, water levels, recovery rates, quantity of water evacuated, pH, and sediment content (using an Imhoff cone).

6.3.9 Develop the well until it is sediment free. An Imhoff cone should be used to determine when there is no further improvement in well sediment levels. As a general rule of thumb, sediment should consist of 3 ml or less in the cone when initial development is complete. A final pH check using pH paper should be done to ensure there is no cement contamination. Even with apparently normal ranges of field chemistry parameters, the water chemistry including pH, specific conductance, temperature, and when possible, dissolved oxygen, and redox potentials, will be carefully scrutinized at the first routine sampling event to ensure the well was properly developed.

6.3.10 Contain all water produced during development. Determination of the appropriate treatment prior to disposal will be based on a chemical analysis of the water. Handle development effluent according to SOP 4.7.

6.3.11 Using flow rates and recovery rates, estimate the discharge rate at which the well can be pumped while not allowing the water level to fall below the top of the screened section of the casing. This estimated sustainable yield of the well should be reported to the Ground Water Monitoring Sampling Coordinator (SC). In some cases, the yield is too low for any purging device. These cases should be labeled as low yielding monitoring wells or dry-out wells (SOP 2.7, "Presample Purging and Sampling of Low Yielding Monitor Wells").

6.3.12 It is sometimes desirable to collect and analyze a water development sample to get early information about potential contaminants. It should be noted that the results obtained from these samples are not given the same weight as would results obtained from a properly sampled well using dedicated sampling systems after full development. For this reason, these samples are identified differently as described in SOP 4.2, "Sample Control and Documentation." The data is nevertheless useful for early tracking of contaminants.

6.4 Field Post Operation

6.4.1 Decontaminate all equipment as described in the SOP 4.5.

6.4.2 Store water produced during development in either secured 55 gal drums or in tankers and handle as per SOP 4.7.

6.4.3 Install a dedicated submersible pump, per SOP 2.8, "Installation of Dedicated Sampling Pumps." In general, wells producing less than 1.5 gpm are equipped with a stainless steel and Teflon bladder pump, or a stainless steel electric submersible pump equipped with a rheostat to control pump speed. If casing volumes are too large, or the depth to water is too great, then normal electrical submersible pumps are installed. Likewise, if sustainable pumping rates exceed 1.5 gpm, any of the above devices can be used depending on quantity of water and depth to water. It may also be advantageous in some circumstances to leave the well without a dedicated pump. The details concerning pump selection are covered in SOP 2.8.

6.5 Office Post Operation

6.5.1 Give field forms to the DC for QA, filing, and distribution.

6.5.2 Report information concerning the type of pump installed, intake depth, and estimated sustainable yield is to the SC.

7.0 QUALITY ASSURANCE RECORDS

7.1 Borehole/Well Construction Log

7.2 Chain-of-Custody Form

7.3 Document Control Logbook

7.4 Well Development Data Form

8.0 ATTACHMENTS

Attachment A—Equipment Checklist

Attachment B—Well Development Data Form

Attachment A

Equipment Checklist

Equipment Checklist

_____ Any applicable permits
_____ Appropriate clothing (i.e., coveralls, steel-toed safety shoes, and gloves)
_____ Applicable documents (i.e., SSP, OSPs, and SOPs)
_____ Barricades
_____ Buckets and brushes
_____ Caution tape
_____ Company ID sign for vehicle (if applicable)
_____ Cooler with ice
_____ Core boxes and trays, black indelible marking pens
_____ De-ionized water
_____ Detergents (Alconox, TSP)
_____ Document control logbook
_____ Drums
_____ Duct tape
_____ Electric water-depth sounder
_____ Field forms (i.e., CoC form, borehole/well constructions form, etc.)
_____ Field notebook
_____ First aid kit
_____ Fire extinguisher
_____ Glass jars
_____ Hard hat
_____ Hearing protection
_____ Imhoff cone
_____ Measuring wheel
_____ Munsell soil color chart
_____ pH paper
_____ PID or FID
_____ Rock hammer
_____ Safety glasses
_____ Sample containers/labels
_____ Sampling gloves (vinyl and nytrile)
_____ Signs listing responsible persons
_____ Soil sample tubes
_____ Steel measuring tape with engineering scale
_____ Steel spatula
_____ Stopwatch or watch with second hand
_____ Teflon tape (4 in. wide)
_____ Water-level meter
_____ 300-ft weighted tape

Attachment B

Well Development Data Form

WEISS ASSOCIATES

WELL DEVELOPMENT DATA

By: ______________________ Sheet ______ of ______

Well No. / Location: ______________________ Job Name: ______________________

Date: ______________________ Job No: ______________________

Development Method(s): ______________________

Depth to Water Before Development (ft): ______________________ Sounded Depth (ft): ______________________

Screened Interval (ft-ft): ______________ Spec. Depth (ft): ______________ Well Diameter (in): ______________

Time	Depth to Water (ft)	Gallons Pumped	Flow Rate (gpm)	Comments (water clarity, odor, methods, sounded depth, etc.)

Well Development Summary

Depth to Water During Pumping (ft): ______________________

Depth to Water After Development (ft): ______________________

Sounded Depth After Development (ft): ______________________

Total Pumping Time (min): ______________________

Total Amount Evacuated (gals): ______________________

Approximate Yield: ______________________

Average Pumping Rate (gpm): ______________________

Pumping Rate Range (gpm): ______________________

Total H_2O Injected (gals): ______________________